Coaxial Helicity Injection and Disruption Mitigation Studies in Support of NSTX-U, ST-FNSF, and ITER

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In support of solenoid-free plasma start-up for the ST, Transient Coaxial Helicity Injection (CHI) has been successfully used on both HIT-II and NSTX to generate substantial amounts of plasma current on closed flux surfaces. Numerous hardware upgrades to the NSTX-U device, that just became operational, will permit more than doubling of the plasma start-up current to over 400 kA, and this is supported by recent simulations using the TSC and NIMROD codes, which also show favorable scaling of the CHI start-up process with increasing machine size.

Application of transient CHI to future devices has been investigated through a conceptual design study of a CHI system for a ST-FNSF, which has resulted in two designs. The first configuration has features similar to the proven NSTX design. In this configuration, the entire blanket structure is electrically insulated from the rest of the vessel. In the second configuration, a toroidal ring electrode is mounted on top of the blanket structure and this is used for CHI discharge initiation. Both configurations support injector flux values equivalent for a 2 MA start-up, using less than 10% of the divertor coil currents. A near-term experimental test of the concept, for this second design, is planned on QUEST.

Predicting and controlling disruptions is an important and urgent issue for ITER. Methods to rapidly quench the discharge after an impending disruption is detected are also essential to protect the vessel and internal components of an ST-FNSF. In support of this activity, NSTX-U will employ three Massive Gas Injection (MGI) valves that are very similar to the double flyer plate design being considered for ITER. NSTX-U will be the first device to operate this valve design in plasma discharges. These valves have been tested off-line and deliver the required amount of gas (~ 200 – 400 Torr.L) to support NSTX-U experiments, which will offer new insight to the MGI data base by studying gas assimilation efficiencies for MGI gas injection from different poloidal locations, with emphasis on injection into the private flux region. The valve has also been successfully operated in external magnetic fields of 1 T.

While the MGI system may be adequate for most disruptions, the warning time for the onset of some disruptions could be much less than the MGI system response time. To address this important issue, a novel system based on the rail-gun concept has been designed, and plans for an off-line experimental test are in progress. The device referred to as an Electromagnetic Particle Injector (EPI) is fully electromagnetic, with no mechanical moving parts, which ensures high reliability after a period of long standby. In addition to responding on the required fast time scale, its performance substantially improves when operated in the presence of high magnetic fields. The system is also suitable for installation in close proximity to the reactor vessel.

This work is supported by U.S. DOE contracts DE-FG02-99ER54519 and DE-AC02-09CH11466.